DOCUMENT RESUME

ED 358 247 CE 062 438

AUTHOR Oliveira, Joao; Pillay, Gerald F.
TITLE Training for New Technologies in Singapore. Training Discussion Paper No. 96.
INSTITUTION International Labour Office, Geneva (Switzerland).
REPORT NO ISBN-92-2-108671-2
PUB DATE 92
NOTE 32p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Basic Skills; Continuing Education; *Economic Development; *Educational Change; *Educational Policy; Foreign Countries; Job Skills; *Job Training; Postsecondary Education; Quality Circles; Secondary Education; *Technological Advancement; *Vocational Education
IDENTIFIERS *Singapore

ABSTRACT

Recent educational reforms in Singapore have essentially been motivated by economic and industrial concerns. Six specific training policies and practices are being implemented to respond to the perceived requirements of new work technologies: (1) development of an increasingly flexible training system, including introduction of a dual system; (2) reorganization of the supply of vocational training by reducing the supply of training as more students go to the polytechnics and as workplace apprenticeship replaces training; provision of most training at the postsecondary level, and absorbing excess faculty; (3) retraining of older workers to increase the aggregate level of qualified workers and to avoid unemployment; (4) provision of basic skills training in the workplace; (5) creation and use of vocational training institutions that provide training in the organizational habits, culture, language, and working styles of potential multinational investors; and (6) training for new occupations through multiskilling. Rapid technological change requires more technical education--but a technical education based on a higher, not a lower or watered-down level of academic preparation. The crux of the matter is that no amount of pre-service education or training will suffice to deal with the changing needs of the workplace brought about by technological development. Signs of the merging of education and training are the expanding catalogues of continuing education courses and provision of technical services to industries by training institutions which are discovering that in order to teach they may also have to learn. Firms in Singapore have been recruiting all graduates of the education and training system, but some still invest in training. They have also discovered that organizational learning through participation of all those involved in production is a condition for survival. (Contains 10 references.) (YLB)

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Training for new technologies in Singapore

by Joao Oliveira and Gerald F. Pillay

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ISBN 92-2-108671-2

First published 1992

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Printed by the International Labour Office, Geneva, Switzerland

Abstract

The economic development of Singapore is primarily based on two assets: its post-independence socio-political stability and its pool of educated human resources. Education and training have been the source spring of the country's economic development. This paper attempts to analyse the recent changes in the country's training policies and practices designed to respond to the challenges of economic, technological and industrial development. Specific features of the education and training systems are analysed to illustrate how the Government is responding to perceived training needs. Recent changes in the way firms are managed and work is organised are also analysed. Out of the three most salient features of the educational and training system - complementarity, comprehensiveness and flexibility - the latter can be considered as the strategy most likely to overcome the country's central vulnerability, namely, the capacity to mobilise its critical assets, that is, human capital.

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I. What is changing in Singaporean education and training policies?

This paper suggests that educational and training policies are intimately related. Indeed, this seems to be the trend, if not the reality, in all countries adopting the new production tools and techniques brought about by electronics and automation. This intimate relationship highlights the increasing importance of education for training - since education provides the basis upon which training policies are implemented. But it also indicates the blurring of the frontiers between the worlds of education and training.

We start this section by demonstrating how the recent educational reforms in Singapore were essentially motivated by economic and industrial concerns. We cannot omit the role of language and social delinquency problems as additional driving imperatives for these reforms. We then move on to analyse six specific training policies and practices which illustrate, each in its way, the provision of training for new work technologies. The section concludes by analysing three trends emerging out of some of the country's training institutions, and which further illustrate the convergence of education and training.

A. The educational reform of 1991

When Singapore took the decision in 1979 to redirect further economic growth from labour-intensive to technology-intensive development, the so-called "Second Industrial Revolution", it also introduced sweeping changes in the education system to enable every pupil to go as far as possible in school before entering the world of work. The vocational training system was revamped in parallel to provide a path for the majority to undertake pre-employment training, either institutionally or industry-based. The vocational institutes, technical institutes and the polytechnics were expanded. Programmes of continuing education and training were initiated for older workers.

Under the education and training system also introduced in 1979 and still operative (until the 1991 reforms are operational) primary pupils have been channelled into three streams, with more time and differentiated curriculum loading for the weaker, and yet provision for transfers between streams, to allow them to develop at their own pace. In the normal stream, 70 per cent complete primary education in six years, but slower learners take eight years in the extended stream (another 20 per cent).

The remaining 10 per cent of the pupils, assessed to be unable to successfully complete regular primary school are catered for in a monolingual stream, and are provided with a specially designed primary programme, also of eight years, concentrating on one language (Singapore education is bilingual) and aimed at basic literacy, numeracy and social skills. These pupils, as well as those failing in the extended stream, are automatically offered enrolment into vocational institutions for programmes of two to five years of full-time institutional courses or combined with work-based traineeship. These prepare them for semi-skilled, skilled and craftsmen level occupations. The average rate of transfer from primary to basic skills training has been 90 per cent. Thereafter, however, their drop-out rates have been high, about 55 per cent. Employers have not found their skills training particularly useful, and only 25 per cent found relevant employment.

Regular secondary education is four years (ten years including primary education), leading to completion at the Ordinary Level, and is of-

fered in a number of ways. There is a special stream followed by ten per cent of students, and the express stream, followed by 60 per cent. The slow stream, called normal stream, is followed by 30 per cent of students, and can lead to a Normal Level or to the Ordinary Level if the student successfully completes an additional year. Students completing secondary education can apply for either skills training or technician training, at the vocational or technical institutes or at the polytechnics.

Education is not compulsory in Singapore. Yet, the system caters for 99.9 per cent of each cohort to completion of primary education. More than 70 per cent of each cohort has continued through to the end of secondary school. Of those finishing the secondary level, about 25 per cent go on to academic studies, 25 per cent to polytechnic technical training, and 25 per cent to technician and skills training. The remaining 25 per cent have gone into employment directly without pre-employment training.

Present economic plans call for an upgrading of the industrial profile and, consequently, upgrading of the workforce. In the face of world competition and the constraints of absolute labour shortage, the economic strategies focus on increasing worker value added and total factor productivity. The country has decided to intensify specialisation in high-tech, brain-intensive production and service activities. As a consequence, it became necessary to intensify efforts to upgrade the level of its entire workforce. A significant part of this effort requires improving the basic level of educational attainment of the entire population, and particularly the still large proportion of the school-going population who fail to join secondary education and for whom the vocational programmes were not a success.

Major reforms have again been introduced across the education and training front, and the education budget was to be raised to six per cent of GDP as of 1991. The core of the 1991 school reforms has been the decision to retain the weakest pupil group in school for a full ten years. They will be offered further education in secondary school, as against the earlier attempt to develop them in a vocational environment. Key features of the 1979 system have been retained, namely the streaming of pupils according to ability, allowing time for each to learn at his own pace. The principle of a differentiated curriculum and language loading has also been retained. Refinements include transfer of streaming assessment to the fourth year of primary school. All primary pupils will now progress into secondary after six years. Based on their performance they will be placed in four instead of three streams at secondary level, the new being a "technical" normal stream for the slowest group. They will concentrate on English, mathematics and computer applications as the third subject. The objective is, besides their own personal and social development, for this group to attain at least basic education at the secondary level, if not the ordinary level, and so be able to take up skilled training.

The second aspect of the 1991 reform has to do with the vocational training system itself, which is operated by the Ministry of Education. The word "vocational" will be abandoned, and skill training programmes will be called "technical education". The major reason is to break away from the stigma of "under-achievers" attached to those undertaking skill-based programmes. At the same time, skills training will be industry-based, with the progressive implementation of apprenticeship leading towards a dual system. In the future, all entrants will need to have completed ten years of secondary school. This establishes a higher academic platform of knowledge skills. We will return to these issues in the last part of the present discussion.

The third aspect of the educational reforms focuses on tertiary education. Up to recently, about half of the pupils who went to two-year junior colleges for pre-university education qualified or were admitted. The policy is to discourage them. Instead, they are being encouraged to take up the three-year industry-oriented technical diploma courses. Two additional polytechnics are being added to the two developed in the 1980s, particularly for them, with a total combined annual intake of

16,000, as opposed to 9,000 in the existing three institutions. A major development will be integration of nursing, up to now under the Ministry of Health, into the fourth polytechnic, as well as banking and insurance, now done by industry training centres. The engineering programmes are likely to be modelled on the technology-oriented approaches characteristic of the Japan-Singapore Technical Institutes mentioned later on in the present paper.

At the university level, capacity is being expanded to take in the reduced number of all pre-university pupils. A second full university was established in 1991, by upgrading the National Technological Institute, and incorporating the Institute of Education. The new Singapore Open University will commence courses in July 1992.

These policy changes illustrate the intimate relationships between economic and educational policies in Singapore. The educational reforms have been motivated by economic imperatives: the country needs a better educated workforce. In terms of trends, firstly, the "critical front" of middle-level manpower training has moved up to the polytechnic level, which will be larger than the skill level in intake, as school pupils are better educated. Secondly, the reformed school programme reflects a major recommitment to basic education. Thirdly, at each level, the quality of education and training is expected to improve, by upgrading and formalising the educational component in parallel with greater participation and integration of industry's contribution to training content.

This constitutes a major departure from conventional practices. Most countries would prefer to lower the requirements to graduate more people at the end of primary or secondary schools; others would water the curriculum down to make it easier for students with academic difficulties. Others would simply maintain the curriculum as it is, and let students pass or fail. In Singapore, the Government accepted the responsibility of changing curricula, increasing the time to achieve goals and adapting teaching methodology to maintain a minimum level of achievement it considered as essential for the entire population. The major motivation was economic: it takes a minimum level of education to make training efficient.

Sections B to G below examine some ongoing changes in the training system which are being implemented to respond to the perceived requirements of new work technologies.

B. An increasingly flexible training system

Over the last 20 years Singapore has developed a comprehensive training system which includes clear policy guidelines and priorities, carefully designed and implemented planning activities, co-ordination and consultation mechanisms with employers, financial schemes, incentives for providers and consumers of training, financial support for individuals and firms, accreditation and certification boards, technical assistance to firms, as well as the direct provision of training through a network of training institutes and polytechnic schools. Graduates from all types of institutes are continuously monitored through tracer studies.

The supply of training is a result of complex decisions which include the expected number of applications for the various streams of post-secondary education, the existing capacity of the technical institutes, the needs of the existing industries, as well as the anticipated needs of prospective industries. Training - most of which is in the form of pre-employment training - not only responds to existing demand, but in a certain way is one of the strategic components of governmental policy to attract new investments.

For a number of reasons, school-based, pre-employment training has predominated so far - followed closely by within-the-firm, on-the-job training. More recently there has been a marked growth in the area of permanent education, particularly in the form of evening courses.

Apprenticeship, in existence for many years but not taken very seriously, was first concertedly launched in 1975, with considerable success in the then burgeoning shipbuilding industry and transport. In the early 1980s, before the expansion of the polytechnics and the vocational and technical schools discussed elsewhere in this paper, it was examined and tried as the basis for general development of workers, along the lines of the dual system, and across the modern trades and skills then emerging. A Scheme for Approved Training Centres to support apprenticeship, run either by companies or industry groups, was also launched in 1981, and some 33 centres have been created with SDF funding. At that time, however, Singapore decided apprenticeship was not a feasible system on which to rely totally, for three major reasons: the lack of industrial infrastructure and experience, the lack of in-industry training and, most important, the lack of trained craftsmen who could serve as masters for the apprentices.

Instead, it was decided in 1982 that the training of skilled workers and craftsmen, to be certified by the National Trades Certificate, be fully institution-based, leaving the employer to complete the industry component on the job. The training centres and institutes of the Economic Development Board (EDB), which were responsible for preparing skilled workers to attract high-tech industries, led the way. This pragmatic policy has since successfully created a strong pool of craftsmen, who now have several years of experience. The first programme for these to become certified mastercraftsmen was introduced in 1987 at the EDB's Precision Engineering Institute.

There are now three such programmes, with a fourth coming onstream, plus a strong pool of skilled workers with others coming onstream. Programmes for training trainers and managers have also been made available by both the Vocational and Industrial Training Board and the National Productivity Board, respectively.

With a decade of preparation, Singapore has now decided to move skills training back to apprenticeship, aiming progressively to institute a full dual system as in Austria, Germany and Switzerland. Mechanisms have been put in place to induce industries and to attract apprentices to enrol in such programmes. The infrastructure and the companies are ready.

The dual system is being introduced for two major reasons. First, it is being adopted in very specific areas. These are areas where pre-employment training is not enough, is not in place (like in most service areas) or is not cost-effective (as in the hotel business), given the relatively small number of trainees and the very high cost of training facilities. In this sense, it is an alternative mechanism which contributes to increasing the reach and the flexibility of the existing training system. But there is also another, very important reason: the dual system is being introduced as an alternative training mechanism for those already engaged in the workforce or for youngsters who start working before they finish a technical education programme. In other words, it is part of the governmental effort to upgrade the level of the entire workforce.

A unique characteristic of the incipient Singaporean dual system is the fact that the industries willing to accept apprentices are being induced to take twice as many apprentices as they will eventually be able to employ. As this model is being selectively introduced in new critical areas - such as in the service and banking sectors - the Government intends to increase the supply of trained personnel in these areas without the need to create new training institutions.

In short, the decision to create the dual system in Singapore has been carefully preceded by the creation of adequate conditions for the system to work. Also, a basic pool has been established in the market place and there are other parallel systems to meet the required level of demand. Once in place, the system will be part of the new and improved total training framework, within which it will play an important, complementary role, while contributing as an alternative instrument to increase the availabiliity of alternative modes of training supply.

C. Reorganising the supply of vocational training

A major challenge governments face throughout the world is to determine an adequate supply of trained people to meet all the demands of industry. If the supply of simple, lower level, skill and craft oriented occupations can be quickly adjusted to respond to the changing needs of the market, the same is not true of the more complex occupations which require two, three or more years of preparation. In the case of Singapore this is even more complex, because male graduates from middle-level technical schools and polytechnics are still expected to spend two years in the army after they finish technical education and before they get their first job. Thus, forecasts of industrial requirements need to be made at least five years in advance.

Thus, some sort of flexible planning is required to reconcile the different variables which must be taken into consideration for the provision of places in the various types of technical institutions. At any point in time, the number of places available and the types of course offerings (apprentice or diploma level) depends basically on the expected behaviour and preferences of the cohort of secondary school-leavers, and the existing facilities and personnel at the technical training institutions. Economic and industrial plans, projected foreign investments, as well as the frequent interaction between planning agencies and industries, as well as annual tracer studies on graduate employment done by the training institutions help reorient the courses and curricula to be offered. In addition, the Government can still adjust quotas for the import of skilled or unskilled labour to correct any imbalances.

Evaluating the effectiveness and accuracy of this planning system is no trivial matter, since the growth of the economy and the labour market in Singapore led to a high demand of graduates from any institution, including those without technical training.

Nonetheless, a few changes in the supply of trainees illustrate some of the characteristics of the reorganisation of pre-employment training in the country. For example, the vocational training institutions managed by the Vocational Industrial Training Board, under the Ministry of Education, and offering essentially apprentice-level courses, were set up in the early 1980s to absorb a total clientele of 24,000 students. Intensive building and teacher training efforts were implemented to create the existing 14 training schools. Over the decade, a few changes occurred, which affected former plans and called for restructuring. The most important of these was the changing preferences of students, some preferring an early entry into the job market, others preferring to go into technical institutions. Other changes were also perceived: the service sector, which became a priority for economic expansion, could directly absorb graduates from secondary schools and provide on-the-job training. In the industrial sector there was a perceived demand for graduates with technical backgrounds rather than with practical skills.

As a result, changes were introduced in the supply of training. First, supply was cut from the planned 24,000 to a maximum capacity of 17,000. Plans are presently under way to merge the 14 existing training institutions into ten institutions with a total capacity of about 15,000. Besides reduction of absolute intake from 10,000 to 8,000, as more go to the polytechnics, the capacity reduction will be the direct consequence of transferring training to the workplace through apprenticeship. In contrast, as mentioned earlier, intake into the polytechnics will increase from the present 9,000 to 16,000. Altogether, under the reforms decided, some 25 per cent of secondary school-leavers will still go the universities annually, 40 per cent will go to polytechnics, 20 per cent will go into technical education, primarily apprenticeship, and only 15 per cent will go into the labour market directly, including public sector agencies.

At the same time, other changes were introduced in the education and training system, as discussed in the previous topics, to guarantee

educational and training opportunities for all - albeit through different delivery systems.

The changes introduced in the training system reflect the classical difficulties with manpower planning exercises, and point to the need to set up alternative, flexible training systems capable of adjusting to the changing characteristics of the demand. Two features of the reorganisation of the vocational training schools deserve further analysis, since these are challenges common to many countries facing reorganisation of their training systems: the strategies for reconversion of the schools and the process of absorbing redundant faculty.

As far as the strategies for reconversion of the vocational schools are concerned, there was a global, comprehensive, non-traumatic approach. First, a significant number of potential students for these schools would stay longer in academic schools, thus improving their general academic level and diminishing demand for early vocational training of the skill type. Second, and as a consequence, most vocational training would be provided at the post-secondary school level and upgraded in status. The change of names from vocational to technical not only reflects the preoccupation with the social stigma but also the upgrading of the technical content of these courses and the broader definition of occupational areas. Third, and as a result of these two changes, the technical schools are being recombined into ten schools, some of which are in the process of construction. These "new" schools will offer some of the traditional trade courses, but others will be progressively moving into new areas, particularly in the services and finance sector, where demand is becoming more acute.

Another characteristic of the transition process worth mentioning - and which often constitutes a barrier for change in many countries - is the absorption of excess faculty. Efforts to retrain faculty to teach other disciplines started well in advance of the implementation of the changes discussed in the previous paragraph. In this process, it became evident that faculty with higher levels of technical education were easily retrainable and reconvertible to new functions. However, those previously hired as specialised instructors and who were originally recruited on the basis of their previous experience as skilled, trade-oriented craftsmen had more difficulty to adjust. Programmes were then devised to retrain some of these instructors to return to industry.

Actually, the Vocational Training Board is facing a very complicated situation. In-service retraining is always "one-down". Some staff have over 20 years' experience and have already been retrained three times. Their move was into pre-vocational training, which is now phased out. Retraining for external employment also has limitations. They are the older ones also. The Training Board has just launched a retrenchment programme, but the fine matching of people and new jobs available is a real problem. As a consequence, emotional stress increases. This is not really an intractable problem, but an area in which high success cannot be claimed.

It is obvious that the example of Singapore is not universally applicable, since not many countries enjoy either the same active job market or the financial conditions to rebuild and modernise their technical schools. Nonetheless, the consistency of the plans, the upgrading of the technical content of vocational training, and the strategies for reconverting faculty illustrate a comprehensive framework worth considering in other countries.

D. Retraining older workers

In the economies of Western Europe and North America, massive programmes of training and retraining of older workers respond to three simultaneous changes: industrial reconversion, demographic change, and the technical requirements of new work technologies. In Singapore, the reason for a programme to retrain older workers is based on a more specific reason, that is, new economic plans to specialise local productive capacity for high-tech, highly paid occupations. Since the early

1990s, Singapore started to transfer labour-intensive industries - particularly those with high levels of automation that require a significant number of relatively low-skilled workers - to neighbouring Indonesia and Malaysia. As a result, the remaining Singaporeans with low levels of education and training may find themselves without jobs in the near future. Retraining for these workers became the alternative to future unemployment.

To increase the aggregate level of qualified manpower and to avoid unemployment at home while expanding abroad, an effort to retrain older workers was launched in the mid-1980s. This programme includes equivalency programmes for primary and secondary education, English language and mathematics upgrading programmes and technical training courses. Given the challenges for upgrading manpower presented by the new industrial policies, a new programme called TIME will provide these same technical courses in languages other than English (Chinese, Malay or Tamil) for those older workers who have not benefited from technical training in the past because of language difficulties. Some of the new schemes are illustrated in the boxes below.

BEST - Basic Education for Skills Training

BEST offers part-time basic literacy and numeracy programmes in four modules each of six months, for workers who have insufficient education to take up skills training and be upgraded. Graduates from BEST are eligible for entry into skill development courses and secondary academic education programmes. A total of 32,787 participants were enrolled in BEST in 1989. The programme is supported by the Skill Development Fund.

WISE - Worker Improvement through Secondary Education

WISE prepares graduates from BEST programmes to sit for secondary-level national examinations in English and mathematics. Each of these two subjects is offered part time in four modules each of six months. There were 22,652 participants in 1989.

MOST - Modular Skills Training

MOST is a programme for those workers who wish to upgrade or acquire new skills. A part-time scheme, MOST is flexible in that it allows workers to participate in the training without disruption to their jobs and to pursue modules relevant to their individual requirements. Presently, MOST offers a range of 124 modules preparing for Certificates of Competency in 33 skill areas. The Skills Development Fund subsidises 70 per cent of course fees for those sponsored by their employers.

Of interest is the combination of disincentives and negative inducements for individuals (threat of unemployment caused by technological upgrade) with positive inducements for individuals and employers to make training available to older workers, such as low-cost, subsidised or free training provided through grants. Workers' unions are also being involved, to mobilise additional funds and to create social and peer pressure for individuals to engage in such upgrading exercises.

E. Basic skills in the workplace

If the causality between education and industrial development is hard to prove, the association between levels of literacy and education and economic development is very clear.

It is also probably not a coincidence that countries first adopting new work technologies are those with better educational levels. Within those countries, the industries and firms using such technologies are also those investing more resources in training, and raising the admission standards. In some European firms, for example, speaking a foreign language or handling telecommunication and computer equipment, including keyboard skills, are becoming universally required basic skills for all employers, including engineers (Oliveira, 1991).

Not only adults and older workers, but all those engaged in productive activities in Singapore are receiving strong signals and incentives to broaden their knowledge base. Several levels of "literacy" are being put in place.

First, the minimum level of entry into the workforce is being upgraded to a secondary school equivalent (ten years of schooling), with strong emphasis on language and mathematics. In the technical schools, the technical subjects are being stressed, with relatively less emphasis on skills. These requirements correspond to the expectation of future changes in the content of jobs, and the need to prepare flexible, adaptable workers with a broad knowledge base.

Beyond these requirements, Singapore introduced in 1986 a Core Skills Training programme called COSEC. This programme is being offered to those already engaged in the workforce, but its contents are also considered as a norm for all new entrants into the workforce.

COSEC - Core Skills for Effectiveness and Change

COSEC was launched in 1986, and consists of six modules each of which are delivered in four sessions of three hours each. Training materials consist of a user guide, texts and exercises as well as videotapes. The topics covered are: communication skills, personal effectiveness, problem solving, economics, quality and computer literacy.

Basic skills training has been used in other developed countries under different names. In North America these programmes tend to be called functional literacy and usually concentrate on basic revision and upgrading in literacy and numeracy. In other countries, particularly in Europe, it also includes training in quality, communication, decision-making and other skills considered essential for dealing with the new work arrangements and the new work technologies (Oliveira and Lau, 1992).

The approach adopted in Singapore illustrates two distinct features of this new trend in training. First, there is an increasing overlap between education and training: the skills

necessary are basic - they are what one would normally expect from schools: how to read, how to write, how to communicate, how to adapt to new situations, how to plan; how to work in groups; how to jointly solve problems, how to use a word processor, how to use statistical techniques, etc. However, these basic skills either were not taught at the schools, or the context in which they were taught was so general that applications did not follow automatically, i.e., they were not directly transferable to the workplace. Hence the need to teach those skills in situations more closely related to the realities of the workplace - even though the skills are the basic, educational objectives of any school system of education.

A second feature of the approach is the perceived need to disseminate such skills to the whole population. That means that not only engineers or technicians need these basic skills, but all the workers within the industry. Ultimately it also includes the suppliers, the clients and the ultimate consumers of the products. Communication skills and concerns with quality, for instance - which became a national obsession in Singapore - are only two examples. A firm can only improve quality to the required levels if everybody involved in the production circuit is deeply concerned with quality: consumers have to complain, suppliers have to conform to norms, employers have to keep up to the standards, clients have to increase their requirements. Even competitors play a key role.

In fact, this phenomenon is not new, and it is part of the classic literature on development economics and on the contributions of cognitive competencies to change (Boissierre, Knight and Sabot, 1985). It has already been observed in other economic spheres, such as in the case of health, family planning or agricultural innovations, where it takes the involvement, participation and adherence of the entire community before such programmes start to take effect. Apparently the same is true of the new technological revolution: it requires upgrading the educational level of the entire population. It is a pervasive phenomenon, which illustrates how it is becoming increasingly difficult to separate where education ends and where training begins.

F. Training institutions as a strategic weapon

Besides the 14 vocational training institutions and the three polytechnics already mentioned, three training institutions were created in the early 1980s to cater to a specific market niche. These are the French-, the German-, and the Japanese-Singapore Training Institutes.

These institutions are similar to vocational training institutions in the sense that they are work-oriented. Their curricula are structured around specific technologies (such as robotics, vision, CAD-CAM) and focus on industrial practices. Students remain at these institutions full time, 48 hours/week, 44 weeks per year - even more working hours than in industries. They receive scholarships and are bonded for three years after graduation. The bonding system is meant to guarantee a supply of trained technicians to the new and upcoming industries operating in key strategic areas approved by the Government.

But these institutions are also close to polytechnics in the sense that they lead to certificates and diplomas, and their courses require an increasingly high level of technical competence - rather than emphasising manual skills.

These institutions were created outside the Ministry of Education as one of the branches of the Economic Development Board. They were to provide a strategic supply of highly specialised culturally sensitive manpower to help attract foreign investment from these respective countries. To fulfil their mission, the training provided by these institutes not only includes highly specialised skills usually required by high-tech corporations but also an in-depth familiarisation with the organisational habits, culture, language, and working styles of potentially multinational investors from these countries.

The Economic Development Board

EDB, a statutory board set up in 1961, is responsible for planning, developing, coordinating and promoting investment in manufacturing and related service industries. Since 1986, in partnership with government agencies, it also promotes the services sector, and the development of local small and medium enterprises. It assists investors to obtain land and factory space, long-term financing, skilled manpower and other services.

Singapore - Facts and Pictures 1990. Singapore: Ministry of Communications and Information, 1990. p. 39.

Contrary to the rest of the training system, which attempts to respond to existing demand, these institutes were created to attract foreign investments, and are an integral part of a broader package of incentives. Even though the direct influence of the supporting countries involved with each respective institution has been diminishing over time, the initial support was sufficient to enable them to reach a level of independence to perform their key functions, which today include four areas: access to latest work technology in these more industrialised countries; access to the headquarters and to the local plants of the key firms of these countries; provision of a suitable space for these countries and firms to display their latest equipment and work technologies in Singapore; and finally, the supply of technical manpower for local firms interested in the adoption of new work technologies.

A few general trends can be noticed as these institutions changed over time - reflecting the level of technological development of the country and the responses required of their training systems.

Let us examine the example of the Japanese-Singapore Technical Institute (JSTI). When it was created in 1982, the critical training needs were in the area of skilled workers for tool and die-making. The emphasis was on skills training. It did not take too much time to perceive that the impact of automation on production required a rather different occupational profile, with an increasingly high technical content.

The changes in the curricula of these institutions also illustrate the tilting balance between education, technical education and training. These are primarily practice-oriented institutions created to supply skilled and technical personnel to high-tech industries. Not being academic institutions, curricula are more flexible, and allow for technology and job-oriented, rather than a discipline-based, training. This is reflected, for example, in the way laboratories and practical activities are organised. Most of the courses are structured around laboratories (CAD-CAM, robotics, automation, etc.). Students are involved in laboratory or industrial type of work since their first day in school. Innovations are introduced almost as quickly as they are in industry, and sometimes even before they are actually used by local industries. Over time, however, and in spite of maintaining their basic work-oriented philosophy, curricula tended to stress more of the basic contents and recruitment of students tended to require a better mathematical background. Today's first-year curriculum is not very different from the curriculum of the polytechnics.

Overall, today it seems that the difference between these institutes and the polytechnics - as far as the curriculum is concerned - is more a matter of orientation than of content: curricula are more integrated in laboratories, projects

and practical activities. Practice precedes or accompanies theory - never follows it. And the realities of production and of the constraints of the shop-floor are ever present in the daily activities. This is not to mean that differences in orientation are not important - after all, the medium is indeed the message. It is very likely that these institutions are training a distinctive breed of workers, with a distinct orientation. However, comparing the trends in both types of institutions, it is inevitable to observe how the institutes are stressing more the learning of the basics, while the polytechnics are progressively interested in emulating the realities of the workplace.

Another interesting characteristic of these institutes imprinted in their mandates is the fact that they are supposed to hand over to the technical education system their innovative courses, after they become mastered and more widely accepted by the labour market. For example, a previously pioneer course on systems analysis was handed over to the local polytechnic, which now runs it as part of its regular programme. An innovative programme on mechatronics discussed in the next topic and originally launched in the early 1980s by the JSTI has already been widely adopted by other institutions, and is now being phased out, to be replaced by a new programme on design of flexible manufacturing systems. Through these institutional mechanisms, these institutes become free to look into new cutting-edge areas in the countries with which they maintain strong links. The fact that the faculty is organised around production functions rather than by academic disciplines makes it easier to promote such internal reorganisations. In fact, it becomes an interesting and automatic mechanism of faculty development.

G. Training for new occupations: The case of mechatronics

It is well documented in the literature that new work technologies tend to increase the need for qualified workers all over the workplace. The simplest evidence is reflected in the changes in the payroll of industries using high-tech production tools: the number of highly-paid, middle-level technicians is increasing very rapidly, as are the recruitment practices of the Institute. In Europe, at least, these firms tend to offer production jobs to workers with technical backgrounds rather than to those without qualifications, or those coming from regular, academic schools (Oliveira, 1991). Just to give one example of this trend: a four-year-old Singaporean firm producing hard disks employs over 500 technician-level workers, out of a total workforce of 5,000 workers.

The effects of new work technologies on workers' jobs and training requirements are pervasive. However, and up to the present stage, three groups of people seem to be affected in very profound ways: machine operators, supervisors and middle-level technical workers in charge of maintenance, quality control and related jobs.

Operators usually have their jobs upgraded and enriched, requiring more knowledge and skills for the operation of automated systems, maintenance and quality control. The range of skills depends on the way the new technologies are deployed, and the new division of work between operators, maintenance specialists and quality control technicians. The training necessary for these changes can be very extensive - up to six to eight months, as in the case of Fiat (Oliveira, 1992), but more typically it is done by the firm itself, through in-service on-the-job training.

Supervisors form another group very much affected by technological change. As the operators and technicians under their supervision become more technically competent, and as the need for direct interaction with them becomes more critical for smooth operations, their roles are dramatically changed. In the traditional work arrangements supervisors manage people to produce the goods. In automated production systems they coordinate people who manage machines which produce the goods. Planning and coordination tasks become much more important than direct inspection and supervision. Listening becomes more

important than telling operators what they should do.

Several changes are occurring with the jobs of supervisors. In some countries, factories are just abolishing a number of intermediate jobs - Japan is known for three-layer hierarchical arrangements - as opposed to the prevailing eight to nine layers typical of most European firms. In most cases, supervisors are becoming integrators of technological information. In high-tech firms, technical background, rather than firm-specific experience, is a major precondition for entering into such supervisory functions. A visible change is in the recruitment for these jobs. In the past, they would tend to go to the most senior, experienced master or journeyman. Today they usually go to the young and communicative, recently graduated from a technical school.

The level most affected by the adoption of new work technologies is that involving the workers in charge of operation, maintenance, quality control, analysis, design, and other direct and indirect engineering functions. In this section we examine one emerging trend affecting such workers - multi-tasking - as it applies to one specific group of workers - those typically involved in production, maintenance or support functions in industries using electronic-based production processes. As tasks become varied, workers need multiple skills to perform them adequately. The mechatronic technicians can be seen as one type of multi-skilled workers.

Even though the idea of multi-skilling has been associated with new work technologies for a long time, the idea of mechatronics was originally developed in Japan (ILO/APSTEP, 1988) and brought into Singapore through the Japan-Singapore Training Institute. Other polytechnics in Singapore also adopted the term - and some of the consequences that came with it. It is the recent evolution of the concept and how it was approached by different institutions in Singapore that interests us.

The age of mechatronics

The skilled worker envisaged is neither a single-skilled nor a multi-skilled worker capable of operating two or more machines or doing a compound job, but an all-round skilled worker with academic aptitude and technical knowledge. Single-skilled and multi-skilled workers might be developed by on-the-job training. But it would be hard to develop all-round skilled workers with practical skills and theoretical knowledge through on-the-job training alone ... (Op. cit. p. 23)

... In the Mechatronics Age the importance of technicians who develop, install and maintain mechatronics machines and production equipment will increase ... basic finishing skills, basic machining skills, basic electric and electronic theories and microcomputers should be made common subjects. (p. 27)

Quote from the Proposals by the Enterprise-Based Training Research Committee of the Vocational Training Bureau of the Ministry of Labour of Japan published under the title: Human Resource Development in the Mechatronics Age.

The Japan-Singapore Training Institute started offering mechatronics courses even before the job market knew what mechatronics was. This was done on purpose - one of the missions of the Institute was to train people for the needs of tomorrow and for the subsidiaries of technologically advanced foreign multinationals to be attracted to the country. In a sense, the idea was that supply would create its own demand.

Not eight years have passed since the first course started, and in 1991 there were four mechatronics diploma programmes in addition to two higher level diplomas offered by four different training centres.

Much can be learned about training for new work technologies by analysing how different training institutions deal with the issue of introducing mechatronics courses. The theme is not new: how to breed hybrids?

In the case of institution A - a polytechnic school - the mechatronics diploma-level course offered to secondary-school graduates is a straightforward combination of previously existing programmes. The new course offering is essentially an electronics specialisation, with 70 per cent of its curriculum on electronics, and the remaining on mechanics. Polytechnic B offers a similar discipline-oriented version, except that the balance is 50 per cent for each area of specialisation. In both cases the mechatronics graduate is conceived as a multi-skilled person. The teachers themselves are not multi-skilled, or multidisciplinary-oriented. Integration is basically a matter for the students to accomplish - possibly in their heads, and later in the workplace.

This approach of juxtaposing existing course offerings to form a new course is clearly reflected in the evening, advanced-diploma course offered by these two institutions to technicians already employed. The individuals applying for these courses already have a technical background in one of these two disciplines. What the course does is to provide the other half, i.e. the areas in which they need more background to complete their mechatronics training. These courses are in high demand, both institutions claim a ratio of 200 applications for 30-40 places - which reflects the interest of industries in this new profile of workers.

Institution C - a vocational training institute attracting students from academic secondary school - has an alternative model, which differs from the ones above in two important ways. First, by expanding on its early interdisciplinary tradition of training electromechanics, its mechatronics course gives relatively equal weight to electronics, electricity and mechanics. The second characteristic of the programme, however, is even more important: it is slightly less discipline-based than in the one offered by the two polytechnic schools. Even though teaching is discipline-based, all teachers are expected to understand and to highlight the interrelation between their specialised discipline and the other technical aspects involved. In fact, all teachers are supposed to further their education in the complementary areas in which they have not been trained. In other words, teachers, before students, are required to integrate knowledge beyond specific disciplines.

Finally, a more elaborated approach to mechatronics training is found in the Japan-Singapore Training Institute. It starts with the idea that there are mechatronics products, such as VCRs - in which electromechanic and electronic components are embedded and cannot be conceived of in separate ways. But there are also mechatronic production tools - such as robots - which can only be conceived, designed, and properly operated and maintained by technicians with the adequate, integrative skills. Thus, the concept of mechatronics is defined as a way of dealing with mechatronic products and production tools. It requires a particular frame of mind involving more than the mere juxtaposition of different knowledge-based disciplines. In this institute, in which there are no discipline-based departments, mechatronics is part of all subjects. More than that, students are involved from the beginning of their training in the development of integrated products, when they learn to think

"mechatronically" about new production technologies.

The problem of dealing with complex phenomena from a variety of integrated viewpoints is not a new one - and has been dealt with in the literature on multidisciplinarity (see, for example Lodahl and Gordon, 1972; Elias, Martins and Whitley, 1982). In fact, it has generally not been dealt with satisfactorily, and many attempts to design interdisciplinary curricula have failed in most circumstances.

To add to the complication is the idea of mechatronics as a property of products and production tools - and not only as an intellectual way of integrating concepts. If this vision is correct, effective mechatronics products could only be conceived by people with the right frame of mind, with the ability to capture the unity beyond the discrete components of the product.

From an empirical point of view, the reader is challenged to analyse why successful VCR and a number of other mechatronic products are a typical creature of eastern Asian countries. An associated implication is the fact that in such cultures, the habit of symbolic thinking (for example, expressing in ideograms) and the cultural exposure to philosophies such as Zen and Tao militate in favour of the idea of integration. Mechatronics would be but one industrial example of fusion and harmony (expressed by the concept of *hu* in the Japanese culture).

One might not need to agree with the concept of harmony or to accept as convincing evidence the present predominance or monopoly of some Asian countries in the production of certain mechatronics products such as automobiles or VCRs. This is not the point: the issue is the emergence of new interdisciplinary needs - and the educational and training responses required. As analysed before, even in an Asian country such as Singapore there are already different ways to interpret and conceive strategies to deal with such emerging needs. Moreover, symbolic thinking - necessary to deal with high-tech - is the ultimate goal of any good educational system and this certainly corroborates the strong association between educational and technological development in Western sócieties.

It is very difficult to evaluate the extent to which the various approaches to curriculum development discussed above are really different, whether they have a noticeable impact on the students, and whether they tend to converge or to differentiate.

When it comes to the actual job, industries display the typical coping strategies of making do with what they have. In some cases, specialised technicians deal with the distinct aspects of the problems. In other cases, mechanics are trained in electronics - and vice-versa - so that they become progressively able to incorporate the missing skills. In a few Singaporean industries visited by the author, mechatronically trained people worked side by side with their discipline-based colleagues, who were progressively introduced into the disciplines lacking in their previous training.

The rapidly expanding job market prevents to observe whether mechatronically trained people receive preference for some mechatronics jobs, and precludes any guess about the future behaviour of the demand. Nonetheless, the fact that industries are willing to pay for their technicians to obtain "mechatronics" diplomas is a positive sign in that direction. At any rate the unique ability of these individuals to tackle problems, to develop their professional identity, as well as to improve their own technical skills remains to be appraised. A major question is whether the training received in each basic discipline is enough for technicians to keep up with the technological developments that affect their jobs.

For the technical training institutions, the new occupational profile of mechatronics presents new challenges about how to structure core curricula, how to cut across disciplinary departments, how to construct work-relevant curriculum while maintaining a basic, disciplinary orientation. We now turn to these questions, albeit in a more general way, by returning to our analysis of the convergent trends between

education and training in the next three sections.

H. Coping with rapid technological change: The merging of education and training

At the outset of the present discussion, we referred to the meaning of the educational reform of 1991 in Singapore. This reform stresses the importance that all students master basic literacy and numeracy skills. Another way to put it is to say that the best preparation for training is good basic education.

Another characteristic of the reform was the change in the name of schools, from vocational into technical. It is obvious, and explicit, that this change reflects an attempt to upgrade the status of occupations. But it is also clear that technological development requires technically trained people - and not only students with a better academic background. At the same time, however, the new curricula and the recombined technical institutions are increasing the academic and technical content of their courses - and de-emphasising the actual training on skills.

Overall, the existing post-secondary training mechanisms in Singapore are geared to cope with 75 per cent of the age cohorts, in addition to the adults and older workers. Only 25 per cent of students go on to pre-college academic education. In other words, technological development requires more, not less technical education - but a technical education based on a higher and not a lower or watered-down level of academic preparation.

The behaviour of the labour market seems to reinforce the idea of this simultaneous requirement for higher levels of education and technical training. For their production jobs, industrial firms consistently hire graduates from technical, not from academic schools. Graduates from technical schools have a clear advantage to occupy supervisory positions - no longer does it suffice to have been in the job for a long time.

Thus, this convergence between education and training brings in new challenges to technical training institutions: how to balance education and training; how to balance what is basic (and lasting) and what is immediately applicable (and probably not very durable) and how to balance relevance (for the short term) with competence (for the long term). Analysing how polytechnics and technical institutes have been changing their curricula may throw some light on these issues.

Throughout the 1980s, training institutions have been flooded with innovations: computer languages, robotics, FMS, FAA, CNC, CAD-CAM and a number of other more or less lasting fads. Given a limited time to teach the curriculum, something had to be given up for job-relevant skills to be taught. Curricula became loaded and shallow, and sometimes the short term prevailed over the long term. The box below illustrates the cycles and modes of curriculum change typical of Singaporean polytechnics, and through which most of the innovations were introduced - or rejected.

Coping with change: typical pattern of curriculum change in Singaporean technical institutes

Every five years: full curriculum revision, including overall evaluation of contents, laboratories, and faculty. Involvement of internal and external advisors. Approval by College Board.

Every two years: introduction of new subjects, or internal subject matter revisions. Approval by the departmental committees formed by the faculty and representatives of industry.

Every year: minor changes in curriculum proposed by faculty. Approval by department.

The early 1990s are starting to reveal a new emphasis. To cope with change - but to protect the integrity of the institutional goals - there is a clear trend to protect the core curriculum: what is basic is basic - and should remain basic. These basic disciplines and contents are concentrated in the first year of the course. During the second year, students are offered a few choices - but their choices are once again constrained by clusters, so that students are not free to choose courses as they do with the menu in the cafeteria. Figure 1, below, illustrates such curricula and clusters. The idea of concentrating on clusters is twofold: first, it attempts to provide the students with an opportunity to integrate different applied disciplines and topics into some meaningful context. Second, it attempts to teach some skills considered essential at least during the transition from the conventional to the high-tech production mode.

A yet unanswered question is whether further curriculum changes will be only a matter of time, whether they will tend to stabilise - or whether they will become part of life. So far, technical schools and employers alike tend to think that they are here to stay: hence the need for schools to insist on the basic, more transferable skills to protect their educational mission - while providing opportunities for updating through specialised courses and continuing education programmes.

I. Continuing education - or continuing training?

The conventional word is continuing education - another sign of the merging between these two concepts. The crux of the matter is that no amount of pre-service education or training will suffice to deal with the changing needs of the workplace brought about by technological development.

The empirical observation is startling: while the catalogue of course offerings in the technical courses shrinks - for the reasons explained above - the catalogue of continuing education expands exponentially: from a few courses to a few dozen to a few hundred, in a matter of five years.

Why are polytechnics and technical training institutions engaging in such avenues? Why so many additions and deletions in the list of continuing education courses? The typical responses are: some topics become quickly obsolete; some new topics must be taught; some basic courses must be introduced. In addition to helping protect the core course of technical education curricula, continuing education brings in new positive dimensions for training institutions and which positively affect the quality of the training they provide.

Special courses and advanced training programmes allow more room for innovation

and recombination of approaches and disciplines than do regular courses. In two of the Singaporean polytechnic institutions, for example, the new programmes on mechatronics evolved from their early experiments with special evening programmes. Progressively this innovative programme was incorporated into the regular offerings - after it had been tried out and adapted to the realities of local industries and the formal requirements of the regular degree programme.

Continuing education also opens up new activities for these institutions - which then can adjust the supply of regular programmes to market needs without threatening their faculty with unemployment: the market for continuing education is expanding, and can absorb eventual surplus of teaching staff. Otherwise, staff would resist changing unnecessary courses - or run the risk of redundancy.

In addition, continuing education programmes provide the teachers with opportunities to interact with older, more mature technicians coming out of the daily confrontation with the realities of the firms. This exposure to concrete problems associated with the latest technologies and to the more practical challenges actually faced by technicians in the workplace can only help to improve the quality of their regular programmes. In this way, institutions can marshal individuals from industry and public sector to help in the programmes and teachers are forced to adapt their styles of teaching to the mental framework and experience of industry workers.

Once again, new work technologies are forcing technical training institutes to revise their approaches and to adapt them to the requirements of life-long education and retraining. Institutions can no longer assume that their training will last for a lifetime: in fact, they are assuming just the opposite - and students already know that they will come back for updates and upgrades.

As a consequence, the need to interact with the daily needs of an industry in the process of technological change requires these training institutions to continuously reflect on the right balance between the knowledge that will last - and which is closer to what is commonly called education, or technical education - and that which needs constant update, and which is closer to the prevailing concept of training. But this is not the end of the story.

J. Technical services: Opening-up training institutions to the environment

More evidence of the convergence of education and training emerges from an analysis of the nature, the meaning and the academic benefits provided in supplying technical services and in the transfer of technologies to industries. Besides providing catalogue and tailor-made courses to industries, the polytechnics and technical institutes in Singapore provide a range of technical services to industries, ranging from tests and measurements to the development of prototypes and typical R&D activities.

The Technology Center at Ngee Ann Polytechnic

In 1990 the Ngee Ann Polytechnic created its new Technology Center to provide services to local industries in areas such as R&D, prototyping, tests, consulting, and technical advice. The aim is to involve at least 50 per cent of the faculty in such activities within three years. Control and incentive mechanisms have been put in place to ensure quality and involvement without sacrificing teaching duties. Departments, such as Systems Engineering, already involve 70 per cent of the faculty in firm-related projects.

Why do these institutions engage in such activities? For a number of reasons. First, they need to be in contact with industries to generate meaningful projects for students to work on. They also need to motivate faculty and to expose them to the latest technologies available in the firms for which they train students. A more important reason is the fact that these institutions are a part of the R&D and industrial policies of the country.

Applied technology groups, comprising staff from different institutions are also put together to tackle specific technology problems. In addition, the technical institutes also house some of the high-tech laboratories set up by the Economic Development Board in coordination with local industries, such as the GSI Robotics Application Laboratory, the Machine Vision Application Laboratory and the FSI MicroCADD Laboratory. These laboratories respond to the needs of local firms and industries. These institutes are not only responsible for training. Training is only a part of their mission to acquire, transfer and disseminate technologies to local industry, together with the skilled workers to deal with them.

Thus, technical training institutions share another characteristic with educational institutions. Effective education is as much a teaching as it is a learning process. Training institutions are discovering that in order to teach, they may also have to learn. As is happening to the high-tech firms, they are also becoming learning organisations.

II. In-firm training: The emergence of teaming organisations?

So far we have been dealing with the supply side of training, that kind of training offered by governmental institutions, and which presumably responds to local demands. The present section attempts to analyse some emerging trends in the kinds of training going on inside high-tech industries.

A clarification is in order: high-tech industries are not necessarily those producing high-tech products. In fact, many labour-intensive firms using conventional technologies can produce high-precision, high-tech products. Avionics, for example (Oliveira, 1991) is an example of a major supplier of the military industry producing extremely low batches of very specialised parts still partly using highly skilled craftsmen and handicraft production techniques. We are interested, however, in those firms using new, high-tech production tools in the production process - independent of the technology embedded in the final product. Firms are increasingly using high-tech equipment for mundane activities such as bottling mineral water or producing pots and pans (Oliveira, 1991).

The central question is: what is happening inside the firms? What is happening to recruitment, training and personnel development practices?

Recruitment. Firms in Singapore have been recruiting all the graduates - and even the drop-outs - of the education and training system. The economic growth of the country, the development strategy adopted and the increasingly sophisticated level of work technology being introduced makes it possible for the market to absorb an almost unlimited number of highly trained professionals. The technical education and training systems have been providing over 5,000 to 7,000 middle-level technical workers per year, and firms have no problem in absorbing them all.

In the case of the three EDB institutes mentioned before, firms have to pay the Government up to US$3,000 to hire such graduates. Virtually all students are hired upon graduation. Demand is clearly there. Moreover, labour policies keep expanding the quota for the import of specialised manpower - thus confirming the insatiable appetite of the industries for highly qualified manpower. In some manufacturing firms it is not uncommon to find from 20 to 30 per cent of the staff in middle level positions - and many internal recruiting efforts are under way to upgrade semi-skilled workers to technical functions.

A selective approach to importing manpower

The re-incorporation of Hong Kong into mainland China prompted Singapore to quickly deploy a human resources strategy to improve the quality of its labour force. Singapore declared itself willing to receive a few thousand workers and their families - provided that they had a technical background.

Training. One could argue that in an economy of full employment, the fact that firms hire all the graduates of the training system is not evidence of the match between training and industrial needs. If this were true, how can it be explained that, in addition to hiring, and even paying a few thousand dollars to the training institutions to hire the graduates who are bound to them, some firms in Singapore still invest in training?

The response to this question is not easy, for a number of reasons. First, the data available on training expenditures in Singapore is not very abundant, much less reliable. In fact, there is a national complaint that companies are not spending much on training. Officials vaguely think it is between one and two per cent of the payroll, but no one really knows for sure. Since all firms have to contribute one per cent of the payroll to the Singaporean Development Fund, most of the training they actually do is included within this one per cent, and is seen by some analysts as a way to recover their contribution.

Second, most of the training is informal, in one way or other. On-the-job and in-service training, for instance, are rarely systematised, and hard to evaluate.

The most well-organised and systematic training activities are those organised and motivated from the outside, by governmental agencies such as the VITB. For example, the efforts to upgrade the educational level of the workers, through programmes like BEST and WISE or the modular training programmes available for older workers who did not have pre-employment training. These kinds of training illustrate the argument of the need to improve the general level of education and training across the board, but also illustrate that governments still have an important role to convince and induce employers to train.

Basic skills was a second type of general programme referred to earlier. For higher level workers and new entrants the COSEC programme mentioned before is being adopted. Most firms, however, still offer courses on language, effective communications and several different courses in the area of quality control. These two courses seem to be a national obsession - and they keep training departments very busy throughout the year.

As far as in-plant technical training is concerned, it would be difficult to identify any clear pattern. Most subsidiaries of multinationals seem to adopt a typical behaviour: whenever a new production line or a new product is to be produced, training is provided either locally or, most usually, at headquarters. Such training activities may eventually involve sending dozens of people abroad for periods ranging from a few weeks to several months. This is the type of training more consistently found under these circumstances. At the other extreme, there are firms with career plan schemes in which the needs and plans of the firms and the individual's aspirations are taken into consideration.

Most of the technical training, however, falls within these two extremes. Very often the individual has to sacrifice his own time (evenings, Saturdays) for training activities in the firm or in permanent education courses. Other times the firm provides training during work hours. Most of the time the costs of the technical training taken outside the firm are borne by the firms, directly or through subsidies or incentives. It is not uncommon, however, to find workers financing their own training - particularly in non-technical training areas, such as computer programming and business administration.

So far, we have analysed the impact of new work technologies on recruitment and training practices. A third, and more important issue, however, is how firms are using and developing the potential of their human resources. This brings us to the issue of organisational learning.

Organisational learning. Industrial engineers are used to the concept of the learning curve. Whenever a new production line starts or a new product comes in, it takes some time for the firm to learn how to improve its productivity and to reach maximum yields.

In the typical hierarchical, Fordist-type organisation, learning is generally concentrated on a few individuals: systems and methods, quality control people, a few selected engineers and technicians, the R&D laboratory, or the industrial engineering department. Workers are seldom involved in the learning process - they are paid to work - while specialists are paid to think. Even suggestion boxes - which have been used in most of these companies for many years - are seldom managed in any serious, systematic way.

However, the high-tech firms of the early 1990s are discovering that they can no longer afford such a division of labour. The major reason is economic: competition is increasing fiercely. Two months' delay in delivering a new product, a slight cost differential, or failure to secure quality can simply drive a company out of the market. Thus, it becomes not only crucial to learn - but to learn fast. This adds a new complexity to the old concept of the learning curve.

The complexity and sometimes the fragility of new materials, the novelty of products and production processes, the need to introduce new products or to design production tools adequate to the new products, and the increasing intolerance towards rejects, all these factors make quick organisational learning an imperative for survival.

The solution firms are finding is to unleash the intellectual capabilities of the entire workforce - with all the risks that it entails. Organisational learning through the participation of all those involved in production thus becomes a condition for survival.

The Disk-Drive Inc.: the "virtuous" learning circle

Disk-Drive Inc. (a phoney name of a real firm) is a Singaporean affiliate of a major US corporation - one of the most successful in the area of disk-drive production. At any time, it produces six to eight different types of disk-drives. The challenges of producing defect-free disk-drives (who wants to buy computers with lousy disk-drives?) are far from trivial. Chips may come in with all kinds of imperfections and surprises. Defects and inefficiencies can arise out of imperfect engineering, inadequate lay out of production lines, insufficient testing capabilities, impurities in the clean-room, mechanical accidents or a less-than perfectly skilled work force - and a number of causes, including random error.

A typical learning curve starts at about 50 per cent and typically ends with 20 per cent or less rejects. Going down from 50 per cent to 20 per cent or less as a major accomplishment thus requiring intensive participation of the labour force. The firm and the individuals learn at the same time - and both need to learn how to learn from each other and how to incorporate the knowledge acquired into the production of the next disk-drive. A "viscious" learning circle is thus created: the firm needs to learn - and quickly - to survive the competition. If a competitor learns quicker, it breaks into the market. But the firm must also be able to create challenging learning opportunities to keep its staff motivated. The problems arising from new technological challenge are the organisational equivalent of food for thought. To survive and thrive, high tech firms are condemned to innovate.

A. How high-tech organisations learn

Training is but one of the components of organisational learning in the high-tech corporations. They learn at least as much from their suppliers, their clients, their competitors and their workers. The box below provides some of the examples of the internal dynamics of the learning going on within organisations. Examples are limited to unskilled and middle-level technical workers.

Organisational learning is not an abstract concept, and does not occur in a vacuum. The examples given in the box below would not exist in the absence of changes in recruitment practices, communication patterns, organisational structures, supervision styles, and work participation. Such changes are necessary to ensure that learning does not become a privilege of some groups, but a pervasive organisational phenomenon.

High-tech firms in Singapore, as is the case in the rest of the industrialised world, are just starting to learn how to come to grips with this emerging phenomenon of pervasive, organisational learning. So far the most conspicuous form of organisational learning is the dissemination of quality circles and of the "quality culture" - which requires permanent readiness of employees at all levels. A critical indicator of learning is not the amount of suggestions received, but the ability of the organisation to analyse, respond to, and implement such suggestions. Organisations which learn to effectively respond to such suggestions are more likely to increase the participation of employees in these programmes. Incentive systems might help - but nothing is more effective to induce learning and motivation than taking people and their suggestions seriously.

The dynamics of organisational learning: three examples

Operators typically contribute suggestions related to their own work, including lay-out, use of tools, patterns of error recognition and general conditions of work. Increasing the number and quality of suggestions by these employees is a priority task for the whole organisation, and involves everyone, including the general manager.

Maintenance and test technicians are expected to identify error patterns arising out of materials, engineering or production process. It does not suffice to troubleshoot and solve immediate problems - they are required to think about long-term solutions.

Diagnosis technicians are professional problem-finders. This is why we prefer to call them diagnosis technicians, and not trouble-shooters. In other words, they solve problems by finding their causes - and by attempting to eliminate them. The more they are asked to understand the mechatronics of the disks, the more they are exposed to different problems and different drives, and consequently, the more they can learn. Further learning has less to do with their former technical qualifications - and more with the organisation conditions for them to learn. The opportunities to talk to technical supervisors and engineers constitute an important additional opportunity for further, continuing learning.

The issue of quality also promotes learning in another way: it polarises energies around concrete targets for improvement. All over the high-tech world, any typical high-tech production line invariably displays two to four targets for quality improvement. These targets commonly originate from suggestion boxes, quality circles or other discussion groups. A target as simple as increasing the efficiency of a machine by 0.01 per cent may involve the attention, the commitment and the involvement of most of the workers of a production line for weeks, if not months. And it can only be solved though a collaborative effort.

A third, and perhaps even more critical factor, is the new work arrangement, reflected in the changes in supervisory functions, by opening up of communication channels between all workers in the organisation, regardless of their location, hierarchical level or technical background. The extent to which high-tech industries are engaging in such new avenues, however, is widely varied, and may serve only as a rough indicator of an emerging trend in the domain of organisational design.

We mentioned earlier that organisational learning entails its risks. At this stage, high-tech firms are barely learning to learn. Already they know the high price to pay, since it involves profound changes in communication and supervisory styles. It also involves opening up information about costs - otherwise, how could employers care about improving efficiency? It involves renegotiating contracts with suppliers on issues of quality control. It risks exposing secrets to competitors - with whom the firm and its employers have to coexist under a new world of simultaneous cooperation and competition. It becomes harder to keep some industrial secrets.

But pervasive organisational learning also involves changes in the profile and the behaviour of workers. If asked to think - and rewarded to think - workers will hardly stop. Societies, in general, and organisations in particular, are only too well aware of the power of the human mind. But this is a matter for another paper.

III. Concluding remarks: In the dire straits of Singapore

Should training be provided *just in time*, on the job, or in response to the immediate demands of the workplace? Or should training be provided *just in case*, in the form of broad-based, conceptually-sound pre-employment technical training? Should training be supply driven or demand driven? Is Singapore providing too little or too much education and training?

These are by no means easy questions and our knowledge about Singapore does not allow us to make any definitive conclusions. But some observations might help dismiss some of the obviously wrong answers, and perhaps help to frame the correct questions.

A first assumption behind the enormous educational and training efforts of Singapore is that technological development will continue to require increasingly higher numbers of better educated and trained people. Will it continue to be that way? Or is this a transient trend? Or is this an over-reaction for lack of greater experience? Only the future can respond to these questions. Nonetheless, it seems that high-tech industries require not only more sophisticated producers - but also more demanding, sophisticated consumers (Porter, 1990). Higher educational levels need to be disseminated throughout the population. Moreover, it is hard to contain rising expectations - and education tends to create its own demand. Even if this assumption is not correct in the sense of a technological imperative, these other factors seem to point to the same direction.

Does high-tech require more education or more training? The experience from Singapore is clearly not all the necessary evidence which is missing to respond to this complex question. In this case, however, the response seems to be: both. In fact, the best response is that adequate education is needed for each level or work, and this necessarily implies more knowledge-based training, as illustrated by the expansion of the polytechnics and the shrinking of the vocational streams. But we got more responses than we asked for. The educational reforms in Singapore illustrate that what was training yesterday became education today - take the case of computers, computer literacy or basic skills training. At the same time, training institutions are also being asked to perform functions which were previously considered as typical education activities such as communication or solving abstract problems.

Apparently the balance between education and training is becoming more a question of semantics and territoriality than one of substance. In practice, however, it seems that the ways in which the organisations of the future will be organised to use and develop the human potential of the workforce will be more critical than any compartmentalised definition of frontiers between different types of teaching and learning practices.

A third question arises from the Singaporean experience: can we plan education and training systems to respond to the demands of high-tech? The response is not a simple one - and certainly is not obvious. The accuracy of the planning and concertation efforts in Singapore cannot be easily interpreted - given the reality of full employment, economic expansion and upgrading of the technological level of the local industries. This is a system characterised by an extreme degree of comprehensiveness, complementarity and flexibility. The most relevant aspect of it, however, is flexibility.

More than anything else, **flexibility** is the most salient characteristic of the strategy of human

resources deliberately adopted by Singapore: flexibility represented by the past and present reforms in the educational system; flexibility allowed by the multiple, coordinated and complementary sources of funding; flexibility which allows students to enter and exit educational and training systems without being confined; flexibility of financing mechanisms such as the Vocational Training Fund (Pillay, 1990) which allows government and firms to fine tune the training supply to the need for skilled workers; flexibility of training provision, by putting in place different self-correcting institutional arrangements to respond to short-term, long-term, and cutting-edge technological changes; flexibility to go beyond strict conceptual barriers imposed by terms such as education and training and which allows the country to develop a variety of orchestrated policies, instruments and mechanisms which, together, can provide quick and adaptive responses to a rapidly changing context.

Vulnerability is both the strength and the weakness of Singapore. Located in the dire straits of Singapore, the country has a unique advantage to remain a privileged entrepot and gateway to the Asian region, but of an entirely different kind. It is no longer dependent on its harbour facilities that enjoy a unique natural geographical location and which allowed the development of the country as a trade post under British rule. But what was a strength was also a vulnerability.

The vulnerability still is there, since the country heavily depends on external markets both for investments and exports, given the limited size of the domestic market. In the absence of other natural resources, it has to rely on manpower to attract such investments - even though it has no major control over investment decisions and over the behaviour of the markets.

Under such circumstances, the ability to quickly reconvert modern infrastructures to serve variable and uncertain needs of its investors and markets can only be supported by a flexible workforce, which is highly educated, highly trained, highly multi-skilled, and who could be able, at any time, to steer this tiny country through the dire straits.

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